# Applicability Of Lean Manufacturing On Operational Performance - A Case Study In The Apparel Industry In Sri Lanka

**** S. K. P. N. Silva***

## INTRODUCTION

The apparel industry in Sri Lanka faced considerable challenges as a result of the removal of Multi Fiber Agreement in 2005, global recession in 2008, and loss of GSP+ in 2010. Delivering high-quality garments at low cost in shorter lead times are the major challenges faced by the apparel manufacturers. Most of the large-scale apparel manufacturers have achieved these challenges successfully. However, small factories find it very difficult to face these challenges and most of them were closed down.

The major problems apparel manufactures face are high raw material and overhead costs, lack of skilled labor force, etc. Due to these reasons, many manufacturing organizations searched for new methodologies in order to overcome these problematic areas. The recent adoption is the Lean Manufacturing to achieve low cost, short lead times and improved quality. Lean Manufacturing can be defined as *"A Systematic Approach To Identify And Eliminate Waste Through Continuous Improvement By Flowing The Product At The Demand Of The Customer"* **(**Introduction to Lean, n.d.). By eliminating waste in the processes, companies can achieve a shorter lead time, lower cost, achieve high quality and in this manner, can achieve a competitive advantage over the others.

## BACKGROUND OF THE RESEARCH PROBLEM

Lean Manufacturing is relatively new to the Sri Lankan apparel sector, and there is not much background knowledge of how it suits the Sri Lankan context. In this research, the author tries to investigate the applicability of Lean Manufacturing concepts in the Sri Lankan apparel sector.

## PROBLEM STATEMENT

Based on the above explanation, a broader research problem can be stated as: *"How can Lean Manufacturing concepts be effectively used to improve the performance of the apparel industry?"*

## OBJECTIVE OF THE STUDY

In answering the research problem, the study sought to accomplish the following research objective.

- To examine the applicability of Lean Manufacturing in apparel production line.

## LITERATURE REVIEW ON LEAN MANUFACTURING

### What is Lean?

Today, Lean has become a business strategy that,

- Reduces lead time in all processes relating to new product development, manufacturing and administration.
- Improves quality, cost and delivery of the final product to the customer.
- Increases overall customer satisfaction.
- Establishes a competitive advantage that will enable sales and profits to grow.
- Builds a culture where involvement and mutual respect encourages continuous improvement.

Lean Manufacturing can be defined as, *"A systematic approach to identifying and eliminating waste through continuous improvement by flowing the product at the demand of the customer"* . **Taiichi Ohno** once said that, *"Lean Manufacturing is all about looking at the time line from the moment the customer gives us an order to the point when*

**Assistant Lecturer,* Department of Electronic and Computer Engineering, Sri Lanka Institute of Information Technology, Malabe, Sri Lanka. Email : niranga.s@sliit.lk

*we collect the cash. And we are reducing that time line by removing the non - value added wastes"* **(Ohno, 1988)**.
Lean always focuses on identifying and eliminating waste and fully utilizing the activities that add value to the final product. From the customer point of view, value is equivalent to anything the customer is willing to pay for the product or service he/she receives. Formally, value adding (VA) activities can be defined as: activities that transform materials and information into products and services the customer wants. On the other hand, non-value adding activities (NVA) can be defined as: activities that consume resources, but do not directly contribute to the product or service. This non value adding activities are the waste in Lean Manufacturing. Waste can be generated due to poor layout (distance), long setup times, incapable processes, poor maintenance practices, poor work methods, lack of training, large batches, ineffective production planning/scheduling, lack of workplace organization etc. By eliminating wastes in the overall process, through continuous improvements, the product's lead time can be reduced remarkably. By reducing lead time, organizations can obtain the following benefits:

**Operational Benefits**

- Enhancement of productivity.
- Reduction in work-in-process inventory.
- Improvement in quality.
- Reduction of space utilization.
- Better work place organization.

**Administrative Benefits**

- Reduction in order processing errors.
- Streamlining of customer service functions, so that customers are no longer placed on hold.
- Reduction of paperwork in office areas.
- Reduction of labor turnover.

**Wastes in Lean Manufacturing :** The waste can be categorized into seven types, which is commonly referred to as the *"Seven wastes"*. **Taiichi Ohno** suggests that these account for up to 95% of all costs in non - Lean Manufacturing environments. These wastes are Overproduction, Waiting, Transportation or conveyance, Over processing or incorrect processing, Excess inventory, Defects, and Excess motion.
Lean uses practically proven tools and techniques such as 5S, One piece flow, Takt time, Pull production, Just-In-Time etc. to systematically eliminate these seven wastes. If these are correctly applied along with employee empowerment, it will bring improvements to quality, cost and delivery of the final product. Those tools help in implementing, monitoring, and evaluating Lean efforts and its results. On the other hand, if these were used without proper understanding, it can spoil Lean efforts in one's organization.

**Lean Approach : Womack and Jones (1996)** have proposed a set of principles for achieving Lean enterprise. Companies should sequentially embrace these principles and incorporate them into their operations. These five principles can be summarized as follows:

**Specify What Creates Value From The Customer's Perspective :** Value should be specified from the customer point of view, not by the perspective of individual firms, functions and departments. If the customer does not pay for an activity, it is a non- value adding activity and should be eliminated.

**Identify All The Steps Along The Process Chain :** This means identifying the value stream. It can be used to identify activities where value is added to the product, and those do not. Once the value stream is mapped, non-value-adding process steps become apparent. The major advantage of this mapping is that it aligns to the product and customer value, rather than processes or functions inside organizations, leading to improvement in whole chains rather than optimization of internal islands within organizations.

**Make Those Processes Flow :** The value added product must flow continuously from the start to finish without interruptions, detours, backflows, waiting, scrap and stoppages.

**Make Only What Is Pulled By The Customer :** The customer should pull the product from the source as needed, rather than process pushing the products onto the customer. This implies that nothing is produced upstream until someone at the downstream needs it. This is exactly opposite of *"batch and queue"* thinking, which suggests mass production and large inventories in advance, which are based on forecasted demand.

❁ **Strive For Perfection :** After implementing the afore- mentioned steps, the team should continuously remove wastes as they are uncovered and pursue perfection through continuous improvement.

❁ **Usage of Lean Manufacturing In The Global Context :** In this section, the researcher tries to explore how Lean Manufacturing is applied in different organizations in the global context. There are several studies that have examined Lean and performance with the majority focusing only on limited aspects of Lean **(Cagliano et al., 2004)**. However, the majority of research on Lean and performance tends to be case based on individual organization experiences. For example, **Robertson and Jones** discuss some ideas for applying Lean manufacturing concepts to telecommunication industry, in particular, to British Telecommunications PLC (BT). They have illustrated some examples of recent changes to successfully implement Lean techniques in BT **(Robertson and Jones, 1999)**. Phillips has considered how far the aerospace industry has adopted Lean manufacturing. Boeing and Airbus industries are two companies, which have adopted Lean. The adoption of Lean ensured the most efficient delivery of new products to the market for Airbus industry **(Phillips, 1999)**. **Dhandapani et al. (2004)** described a case study of a steel plant in India, which has realized a substantial production and inventory cost reduction by the implementation of Lean practices. **Rahman, Laosirihongthong and Sohal (2010)** presented the impact of Lean strategy on operational performance in Thai manufacturing companies. The findings provide further evidence that Lean practices are significant in enhancing operational performance in Thai manufacturing companies. **Dickson et al. (2009)** describes applying Lean Manufacturing techniques in an emergency unit of a hospital and has shown improvements in patient flow, patient satisfaction and, consequently, an increase in patient visits. **Comm and Mathaisel (2005)** discuss about applying Lean to a labour intensive textile firm in China. The results have shown that production efficiency for one of its most troublesome textile products could be improved by applying Lean to its labour-intensive operations. Lean has been applied to red meat processing industry in United kingdom. **Simons and Zokaei (2005)** highlight the benefits of Lean production in one specific manufacturing area, the *"cutting room"*, where meat is split down from a carcass into retail cuts of meat. After applying Lean concepts, it has improved the productivity and quality of red meat cutting lines.

Based on the global review, it can be seen that Lean Manufacturing principles were adopted across the world several years ago. However, in the Sri Lankan context, most of the organizations have started implementing Lean concepts recently.

## RESEARCH APPROACH

As shown in Figure 1, a comprehensive literature review was carried out on Lean Manufacturing. Then, a well reputed apparel manufacturing organization was selected based on judgmental sampling techniques to carry out the implementation study. The research was carried out in the month of February 2008, and past three months average operational data were collected in the selected line. Then a garment style was selected in order to analyze the current state of the production process by collecting the relevant data. Based on that data, some target goals were set up. In order to carry out this task, a cross-functional team with machine operators, mechanics, executives and managers were formed. Then various improvement proposals were identified to reduce the non-value adding waste in the process. After that, those suggestions were implemented and results were observed. Finally, the conclusion was made.

## FINDINGS AND DISCUSSION OF THE STUDY

The case company is one of the leading apparel manufacturers in Sri Lanka, and it has 20 production lines along with raw material, cutting and finishing departments. The following steps were carried out in order to convert batch production line to Lean production line. In this research, production line number 3 was selected judgmentally, and the past 3 months average operational data was collected. According to base data, some targets were setup to achieve after the kaizen event (Table 1).

❁ Takt time was calculated for the selected style (# 2046) in production line 3.

| | |
|---|---|
| Customer demand | = 10,518 garments (gmts) |
| Finished good stock as at 11th Feb. | = 673 gmts |
| Remaining quantity | = 9845 gmts |
| Customer delivery date | = 29th Feb. |
| Dates remaining for delivery date | = 14.5 days |

**Figure 1: Research Approach - Step By Step Process**

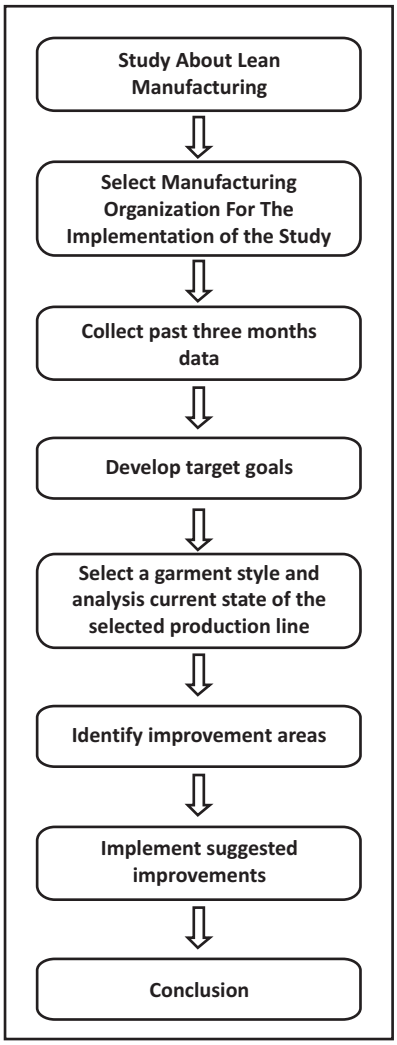



**Table 1: Base Data**

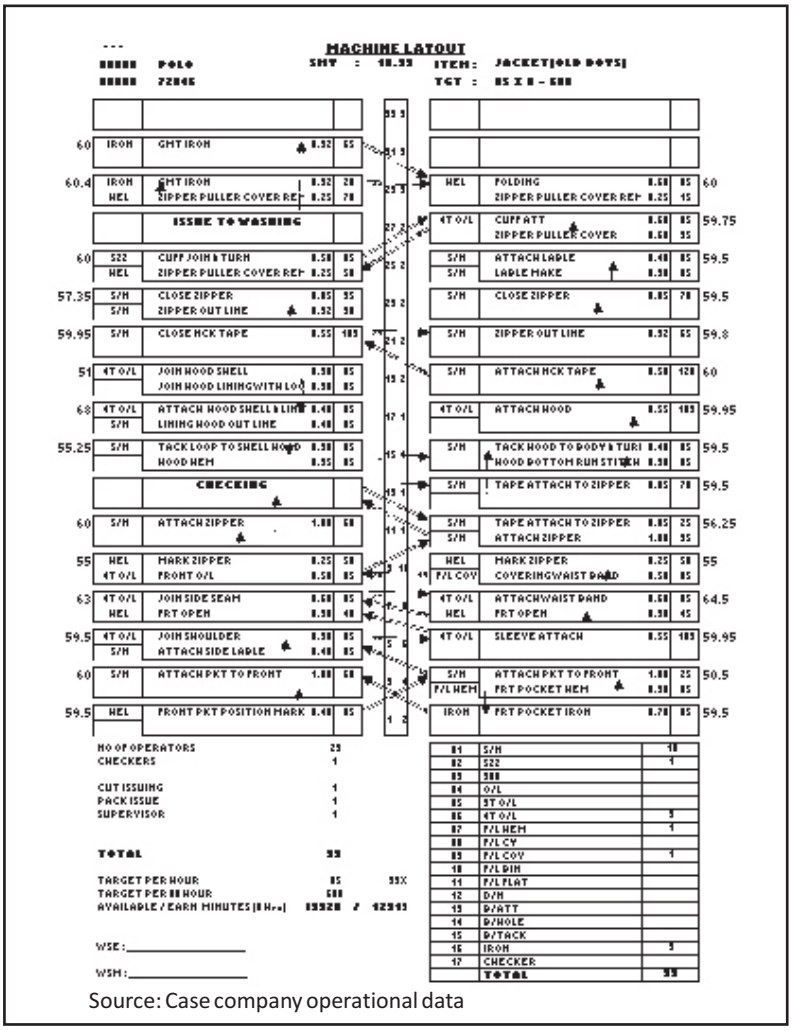
| Area | Base | UP/Down |
|---|---|---|
| Productivity | 35.44 S.M.V./Person/hr | 25% up |
| Defects % | End line 9.3% | 50% down |
| Space | 89.14 $m^2$ | 20% down |
| 5S | 1.91/5.0 | +1 up |
| Manufacturing Lead Time Manufacturing Lead Time = Sewing time + Washing time + Finishing time | 525 mins | 30% down |
| Takt Time (T/T) | 0.75 mins/ gmt | 0.75 mins |
| Work In Progress (WIP) | 557 gmts | 30% down |

Source: Case company operational data

Available working time per day = (60*9-30) = 510 min
Net operating time = 14.5 * 510 = 7395 min
Takt time = Net operating time / Total demand
= 0.75 min/gmt = 45 secs/gmt

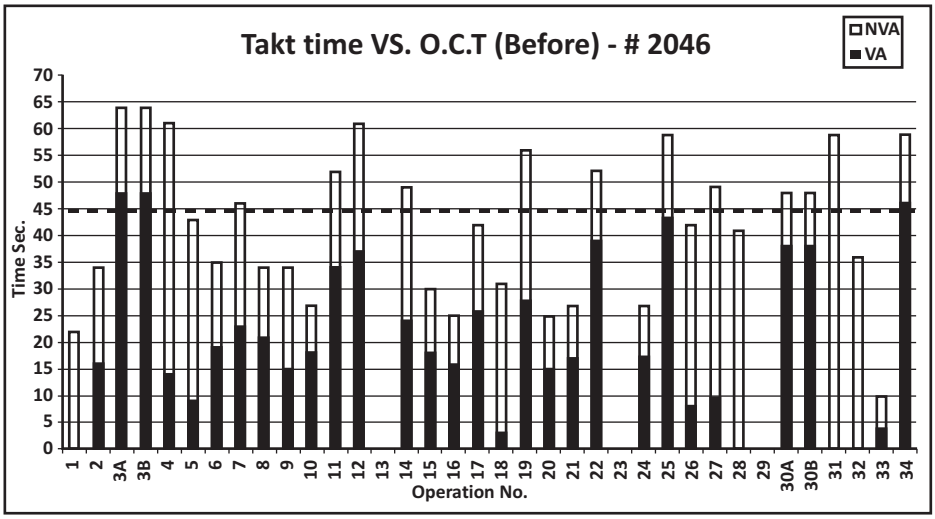
❁ Before doing any improvements, the existing line layout (Figure 2) was examined thoroughly and the time study was done (Figure 3).

**Figure 2: Before (Current) Layout**




Source: Case company operational data

**Figure 3: Takt time Vs. Operator Cycle Time (O.C.T.) (Before)**




Source: Based on researcher's observations and participants insights

❁ After doing the time study (Figure 3), it was observed that this layout is not balanced to takt time. Because of that, the lead time was high and there were excessive inventories everywhere.

❁ This production line needed improvement. As an initial step, workplace was organized according to the 5S process. Following actions were taken during the 5S process.

❁ Remove all unnecessary items from every work station of line number 03.

❁ Training was given to the employees on how to store and handle materials and equipments.

❁ Implement a daily cleaning checklist and monitor it by a responsible person.

❁ Carry out weekly 5S audit by a patrol team.

❁ Reward the best 5S practice team monthly.

❁ After these steps, kaizen techniques were applied to areas in line 3, which were not balanced to takt time (Table 2).

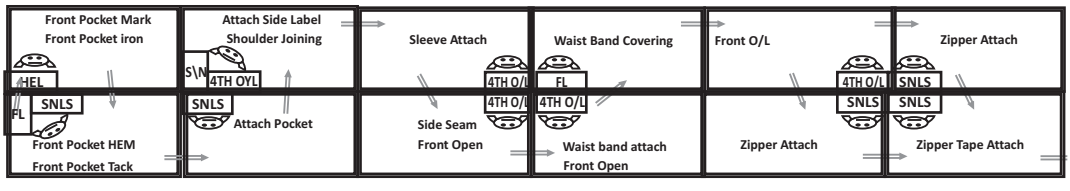
**Table 2: Point Kaizen Suggestions**

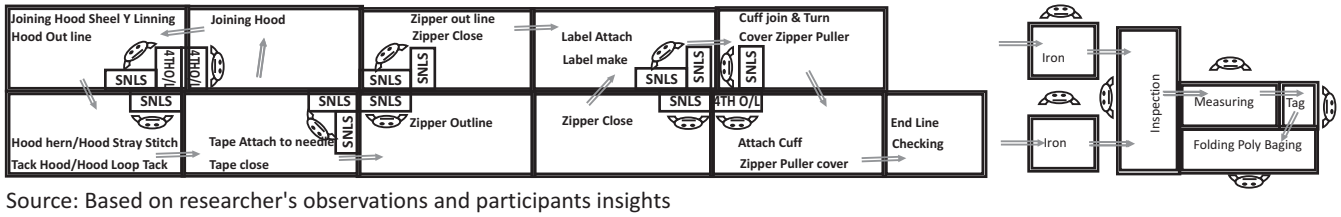
| Operations | Suggested Improvement | Expected Saving (sec) |
|---|---|---|
| Front pocket position mark | Fixed the marking board. | 10 |
| | Change the moving depiction of the mark pocket. | 3 |
| | Use the powder pen to mark the panel. | 3 |
| Front pocket iron | Iron both pockets together. | 6 |
| | Put the pocket board into size wise box. | 6 |
| Front pocket hem | Fixed the extension to keep the pocket. | 6 |
| Pocket attach | Instead of getting the pockets from one side, get the pockets simultaneously. | 5 |
| Shoulder joining | Change the work place area to make it easy to get the panel. | 5 |
| Waist band attach | Stop measurement checking of front open. | 2 |
| Zipper attach | Split the operation to achieve the takt time. | 12 |
| Front over lock | Reduce bust. | 3 |
| Tape attaching | Use the top side attachment and modify the foot. | 10 |
| Hood hem tack | Change the sewing method. | 3 |
| Hood joining and out line | Minimize the operator motion. | 3 |
| Attach hood loop | Loop attach without fold. | 3 |
| Tape attaching to neck | Change the machine position. | 3 |
| Cuff joining | Replace the automatic with under bed trimming machine. | 3 |
| Cuff attaching | Reduce the distance. | 3 |
| Checking before wash | Change the work routine. | 3 |
| Iron checking | Combine iron checking. | 3 |
| Checking after wash | Reduce the folding of the garment. | 3 |
| | Develop the checking table angle. | 3 |
| **Total** | | **97** |

Source: Based on researcher's observations and participants insights

❁ Then the layout was rebalanced according to takt time by implementing suggested improvements in point kaizen session. Again, time study was conducted and after (proposed) layout (Figure 4) and time study chart (Figure 5) are

**Figure 4: After (Proposed) Layout**

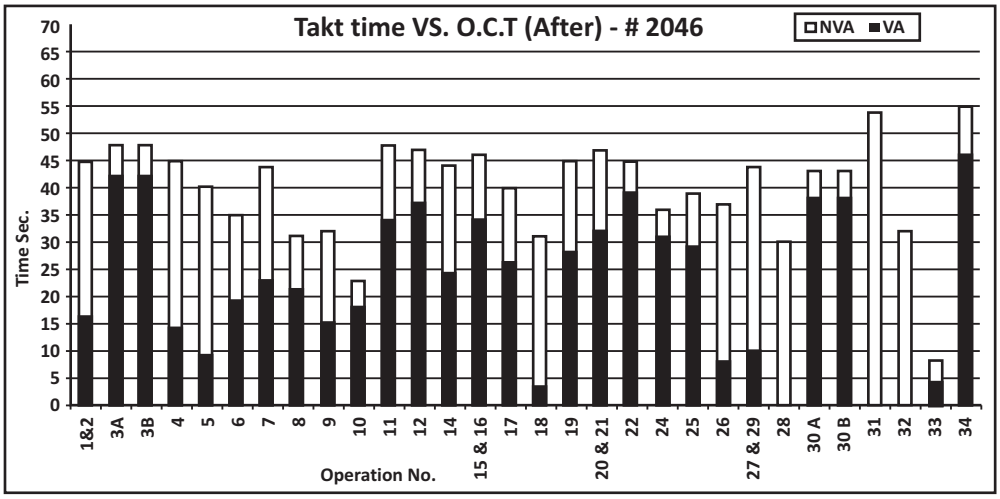





Source: Based on researcher's observations and participants insights

presented here. The new layout was almost balanced to takt time.

**Figure 5: Takt time Vs. O.C.T. (After)**




Source: Based on researcher's observations and participants insights

**Table 3: In-line Defect Summary**

| Type of defect | | 08/02 | 09/02 | 12/02 | 13/02 | 14/02 | 15/02 |
|---|---|---|---|---|---|---|---|
| Construction defects | Joint uneven at underarm | 0 | 12 | 1 | 0 | 0 | 0 |
| | Open seam at sleeve attach | 0 | 0 | 2 | 0 | 0 | 0 |
| | Zipper attach high-low | 0 | 3 | 1 | 10 | 0 | 3 |
| | Pocket attach uneven | 2 | 14 | 7 | 4 | 3 | 5 |
| | Zipper outline uneven | 2 | 0 | 0 | 3 | 1 | 0 |
| | Hood attach seam not balanced | 0 | 0 | 0 | 0 | 0 | 4 |

Source: Based on researcher's observations and participants insights

**Table 4: End-line Defect Summary**

| Type of defect | | 08/02 | 09/02 | 12/02 | 13/02 | 14/02 | 15/02 |
|---|---|---|---|---|---|---|---|
| Oil marks | | 2 | 3 | 18 | 3 | 4 | 1 |
| Stain marks | | 0 | 2 | 0 | 7 | 20 | 11 |
| Fabric defects | | 0 | 5 | 8 | 16 | 8 | 3 |
| Ironing defects | | 0 | 5 | 11 | 07 | 4 | 0 |
| Construction defects | Uneven neck out line | 0 | 1 | 0 | 2 | 3 | 0 |
| | Open seam at sleeve attach | 4 | 3 | 5 | 0 | 4 | 0 |
| | Joint uneven at underarm | 0 | 6 | 4 | 1 | 0 | 0 |
| | Zipper attach high-low | 0 | 4 | 9 | 0 | 0 | 0 |
| | Open seam at edge of zipper tape close | 0 | 0 | 9 | 7 | 5 | 0 |
| | Open seams at hood attach | 0 | 0 | 4 | 1 | 0 | 0 |

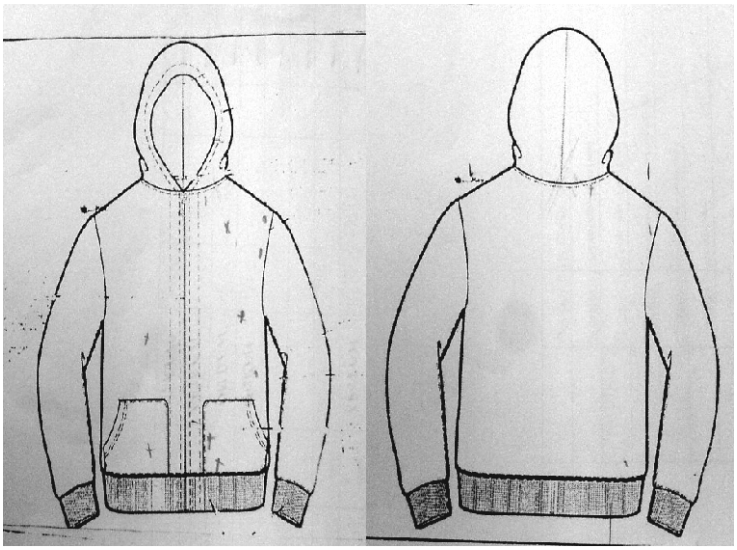
Source: Based on researcher's observations and participants insights

☸ In order to reduce the defects, some quality actions were carried out. As the initial step, past 6 days in-line (Table 3) and end-line (Table 4) defect summary of style # 2046 was captured.

☸ Then these problems were analyzed using methods such as 6W2H, 5 Whys, 4M and Fishbone diagram. After finding the causes, the following actions were taken to reduce these defects.

☸ **Oil marks :** Gave a Position diagram (Figure 6) of the garment to mark oil marks to monitor the area at the end line inspection. Then it became easy to track the sewing machine which generates oil leaks.

**Figure 6: Oil Marks Inspection: Front and Back**



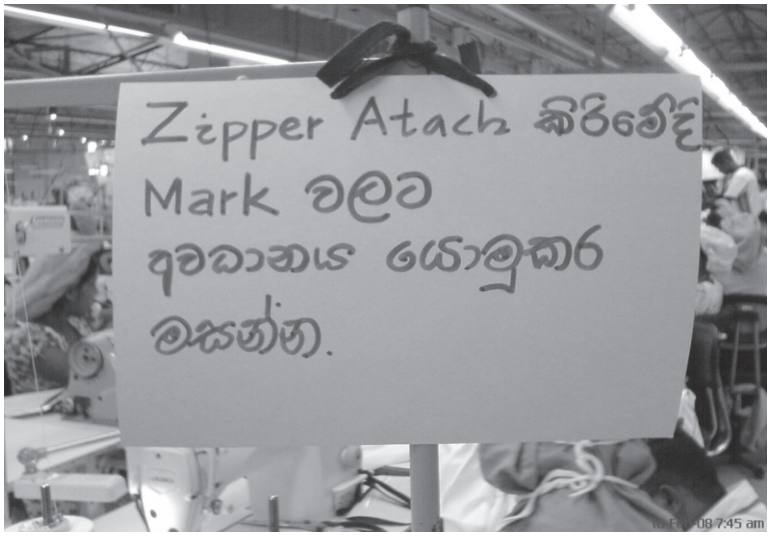
Source: Based on researcher's observations and participants insights

☸ **Fabric Damages :** Inform panel inspection in-charge about the current situation and advise him to recheck the remaining quantity.

☸ **Ironing Defects :** Give instruction to the operator about the correct method of ironing.

☸ **Construction defects :** Give instructions to sewing machine operators by means of visual boards and train them to sew correctly (Figure 7).

**Figure 7: Visual Instruction Boards**




Source: Based on researcher's observations and participants insights

☸ In order to reduce machine breakdowns, the following actions were taken for Flatlock sewing machines. This is the

**Table 5: Flatlock Machine Breakdowns**

| Type of Breakdown | Repeat Duration | Reason | Solution | Repair Time Duration (min) |
|---|---|---|---|---|
| Needle brakeage | Randomly | Wrong handling | Change handling | 0-45 |
| | | Wrong timing | Adjusting machine timing | 0-45 |
| | | Wrong needle size | Change needle | 0-45 |
| | | Fabric thickness | Change needle | 0-45 |
| Thread slip | Randomly | Wrong thread tension | Adjust thread tension | 5 |
| | Randomly | Change machine timing | Check needle /Lopper timing | 10-30 |
| Machine motor breakdown | Rarely | Voltage /heat problem | Change motor/belt | 10-30 |
| Thread trimming | Rarely | Air pressure drop | Correct air pressure | 2 |
| | | Screw loose | Correct trimmer timing | 10-30 |
| Fabric puckering/ damages | Randomly | Wrong machine adjustment | Change machine setting | 10-30 |
| Thread brakeage | Randomly | Machine speed | Change proper speed | 1 |
| | | Thread tension | Adjust thread tension | 5 |
| | | Wrong rewinding | Remove thread cone | 1 |
| | | Use damage needle | Change needle | 5 |
| | | Colour changing | Change machine setting | 5 |

Source: Based on researcher's observations and participants insights

type of machine which generates higher number of breakdowns compared to a single needle, overlock etc. (Table 5).

- In order to minimize these breakdowns, a list of activities were prepared for machine operators.
- Operators should clearly understand about his/ her own operation.
- Check the needle (blunt or not) hourly.
- Pay attention about the needle, looper & bobbing threading every time.
- Clean the machine hourly (1-2 min).
- Pay attention about machine sound (parts loosen or not).

Some activities were done by mechanics. These checkups should be done daily, weekly and monthly/yearly (Table 6).

- Machine speed should be adjusted based on operator target.

**Table 6: Mechanic Checklist**

| Time | Description |
|---|---|
| Daily | Inspect all machines, Check oil level, Check machine sound |
| Weekly | Check and clean machine, Check safety items |
| Monthly/ Yearly | Servicing should be done on time, Change machine service card at appropriate time, Check machine condition (oil level, loose part, part changing), Check motor, Belt condition, Regular technical training for mechanics |

Source: Based on researcher's observations and participants insights

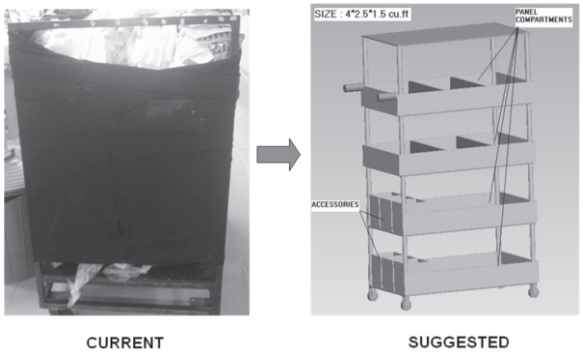



**Figure 8 : Current - Modified Trolley**

Source: Based on researcher's observations and participants insights

❁ The next consideration is material flow analysis. Material handling was improved by providing a *"Supermarket"* (temporary storage area for inputting raw material) at the beginning of the production line. Also, existing material handling trolley was modified by adding compartments to put panels and accessories accordingly **(Figure 8).**

❁ It was proposed to replenish material (cut) every hour with the amount of one hour production target. Based on this requirement, cut issuing process was improved in the cutting department by establishing a supermarket. Thorough study was done on the material issuing process in cutting department by using a spaghetti diagram **(Figure 9).**

❁ First, the duty of the Issue girl was examined and time study was done to identify value adding and non-value adding activities (Table 7).

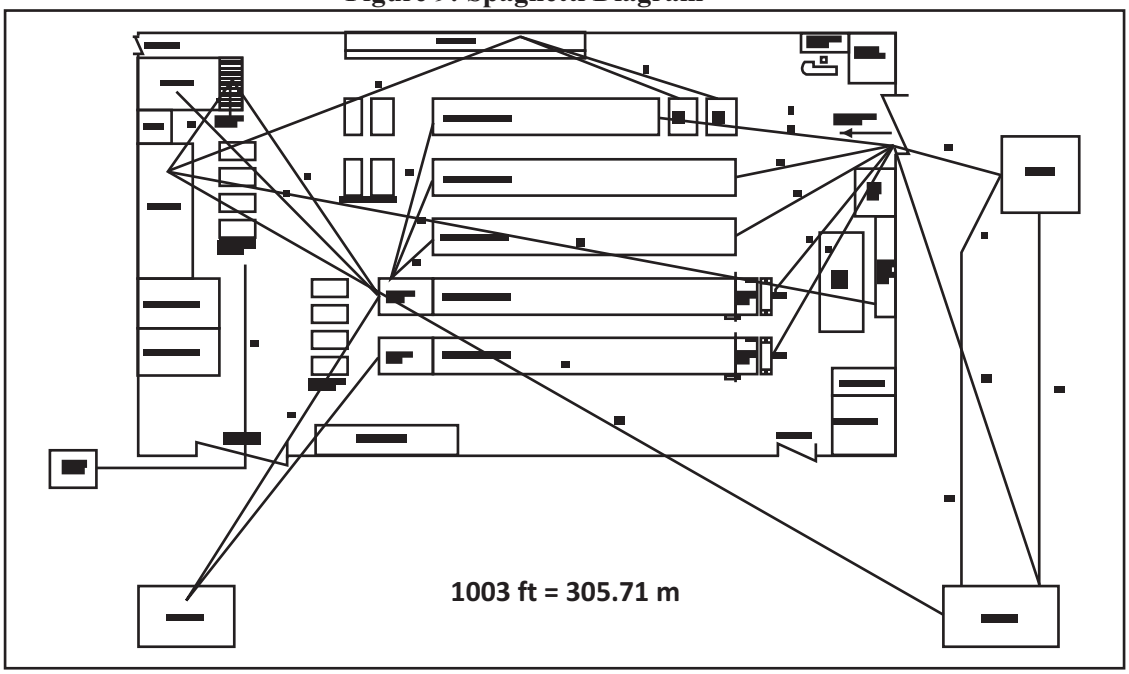
**Table 7: Current Issue Girl's Duties**

| No. | Operation | Time (min) |
|---|---|---|
| 1 | Go to cutting department | 5 |
| 2 | Count the cut (NVA - eliminate) | 12 |
| 3 | Pick labels, zippers | 2 |
| 4 | Prepare the trolley | 2 |
| 5 | Bring the trolley into the production line | 3 |
| 6 | Put cut panels into bins | 4 |
| 7 | Count labels, zippers (NVA - eliminate), put to box | 18 |
| 8 | Handover the cut to machine operators (M/Os) | 5 |
| 9 | Take zippers to steam | 3 |
| 10 | Bring tapes from washing department | 10 |
| 11 | Handover tapes, labels, sippers to M/Os | 5 |
| 12 | Check damages and take them to cutting department | 5 |
| **Total** | | **74** |

Source: Based on researcher's observations and participants insights

❁ It took 74 minutes to prepare one cut and the time was reduced to 44 minutes by removing non value added activities. First, a Spaghetti diagram (Figure 9) was drawn to identify the movement of issue girl and it was found that she walks around 1003 ft to arrange one cut. This is because she has to go for various sections (Panel inspection, Printing & Embroidery & Binding section) to prepare the next cut.

**Figure 9: Spaghetti Diagram**




Source: Based on researcher's observations and participants insights

❁ Based on the Spaghetti diagram, layout changes were done for Panel inspection, Printing and Embroidery and Binding sections. After doing those changes, the travel distance was reduced to 300 ft. Based on these modifications, the new schedule was prepared for the issue girl (Table 8).

**Table 8: New Duty Roster of Issue Girl**

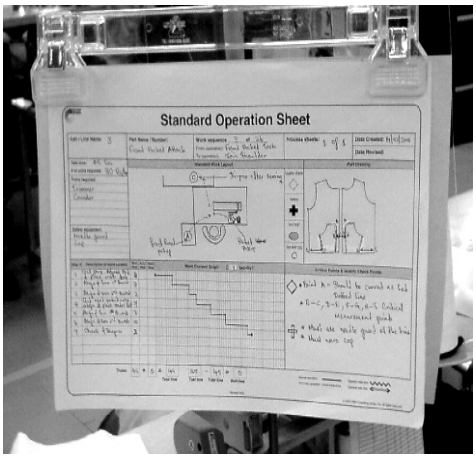
| Time | Activity |
|---|---|
| 6.55 a.m. | Get the trolley ready with hourly requirement of cut and accessories, and departure from cutting department. |
| 7.00 a.m. | Arrival to the band and fill the super market. |
| 7.15 a.m. | Check the balance quantity of operators and fill their need. |
| 7.30 a.m. | Check the board that displays data about issuing and receiving times of garments from washing department. If there's a delay, inform the washing department about that. |
| 7.40 - 8.00 a.m. | Replace damage cuts; return balance threads and prepare the trolley for the next hour. |

*** This cycle will continue hour by hour.**

Source: Based on researcher's observations and participants insights

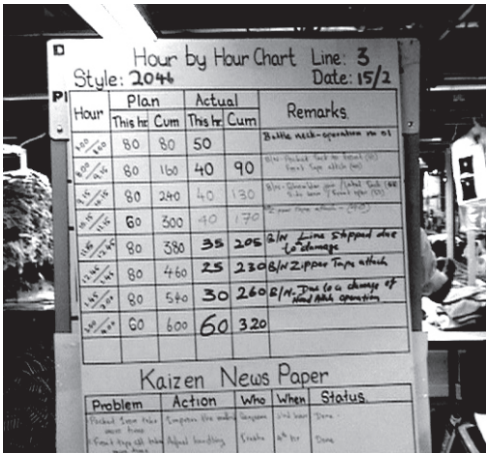
❁ Standard operation sheets (Figure 10) were developed for every operation and they were hanged in front of operators. Also, Hour by hour chart and SQDC (Safety, Quality, Delivery and Cost) boards were also implemented

**Figure 10: Standard Operation Sheet**



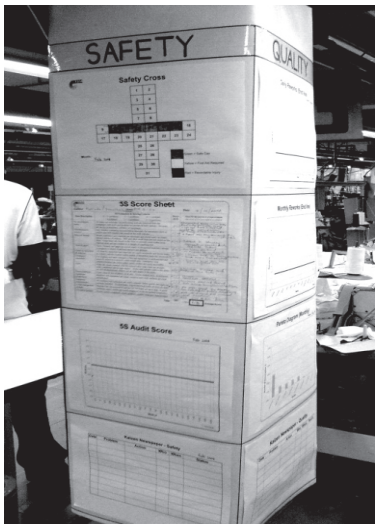

Source: Based on researcher's observations and participants insights

**Figure 11: Hour By Hour Chart**




Source: Based on researcher's observations and participants insights

**Figure 12: SQDC Board**




Source: Based on researcher's observations and participants insights

(Figure 11 and 12). These boards helped to visualize the current situation of the production line, and if there are problems, they can be easily tracked and solved.

❁ After applying the above mentioned steps, the following results were monitored for a period of one month (Table 9). It can be seen that all the parameters have improved remarkably. This is basically due to the removal of non-value adding wastes in the manufacturing process.

**Table 9: Results**

| Head | Base Line | Target | Achieved | Result |
|---|---|---|---|---|
| Productivity | 35.44 SMV/Per/ahr | 25% up | 54.93 SMV/Per/hr | 55% up |
| WIP | 557 gmts | 30% down | 300 gmts | 45% down |
| Lead Time | 525 min | 30% down | 225 min | 55% down |
| End Line rework | 9.3% | 50% down | 4.2 % | 55% down |
| Space | 89.14 m2 | 20% down | 71.00 m2 | 20% down |
| 5S | 1.91/ 5.00 | + 1.00 | 3.00/5.00 | 2.91 |

Source: Based on researcher's observations and participants insights

## CONCLUSION AND RECOMMENDATION

Modern managers find it difficult to identify the key areas and practices, which can be used to eliminate waste in their processes. Based on the practical validation conducted, it can be seen that Lean Manufacturing can be effectively applied to the apparel industry as to improve the production process by identifying and removing wastes. The case study presented in this paper has shown that the wastes such as transport, inventory, motion, and defects can be reduced, which in turn improves the productivity of the organization. In order to accomplish this task, the managers of the case company have to implement approaches like 5S, One piece flow, Cellular manufacturing, etc. In order to continuously reduce or eliminate waste, management of companies need to apply different Lean tools and techniques accordingly while giving adequate training to their employees. It is recommended to apply Lean Manufacturing to other production lines in order to improve the operations in the whole production department. Furthermore, organizations of similar type can use the research outcomes as a knowledge base to identify their wastes and come up with suitable remedies. Findings of this research can be valuable to other organizations of Sri Lanka, which hope to implement Lean Manufacturing in the near future.

## LIMITATIONS AND SCOPE FOR FUTURE RESEARCH

The study has been conducted for a selected garment style in an organization in the apparel sector in Sri Lanka. In future, researchers can deploy Lean Manufacturing for different styles, for several organizations across the apparel industry.

## REFERENCES


1. Cagliano, R., Caniata, F. and Spina, G. (2004). "Lean, Agile and Traditional Supply: How Do They Impact Manufacturing Performance?", *Journal of Purchasing & Supply Management*, Volume. 10, pp. 151-164.
2. Comm C.L. and Mathaisel D.F.X. (2005). "An Exploratory Analysis in Applying Lean Manufacturing to a Labor Intensive Industry in China", *Asia Pacific Journal of Marketing and Logistics*, Volume 17, Number 4, pp. 63-79.
3. Dhandapani, V., Potter, A. and Naim, M. (2004), "Applying Lean Thinking: A Case Study of an Indian Steel Plant", *International Journal of Logistics: Research and Applications*, Volume 7, Number 3, pp. 239-250.
4. Dickson E.W., Singh S., Cheung D.S., Wyatt C.C., and Nugent A.S. (2009). "Application of Lean Manufacturing Techniques in the Emergency Department", *The Journal of Emergency Medicine*, Volume 37, Number 2, pp. 177-182.
5. Introduction to Lean (n.d.), viewed on May10,2010 http://www.mamtc.com/lean/intro_intro.asp
6. Ohno T. (1988), *Toyota Production System*, Productivity Press, New York, p 9.
7. Phillips M. (1999). "Agile Manufacturing in the Aerospace Industry: An Industrial Viewpoint", *International Journal of Agile Management Systems*, Volume 1, Issue 1, pp. 17-22.
8. Rahman S., Laosirihongthong T. and Sohal A.S. (2010). "Impact of Lean Strategy on Operational Performance: A Study of Thai Manufacturing Companies", *Journal of Manufacturing Technology Management*, Volume 21, Number 7, pp. 839-852.
9. Robertson M. and Jones C. (1999). "Application of Lean Production and Agile Manufacturing Concepts in a Telecommunications Environment", *International Journal of Agile Management Systems,* Volume 1, Issue 1, pp. 14-16.
10. Simons D. and Zokaei K. (2005). "Application of Lean Paradigm in Red Meat Processing", "*British Food Journal*", Volume 107, Number 4, pp. 192-211.
11. Womack J. P, Jones D.T (2003), *Lean Thinking*, 1st Free Press ed., New York: Free Press, pp. 16-26.